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Climate Change Detection Using Bayesian Change Point Method for Improving the Traditional Cropping Calendar in DIY Province Indonesia

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Abstract

"Pranoto mongso" or provision of the season is an agricultural activities calendar based of the traditional knowledge and local wisdom. The calendar includes various aspects of phenology and other natural phenomena which was used as the guidance not only in farming activities but also in disasters mitigation (drought, crop bullies attack, flood, etc.) that may arise at certain times. However, due to some climate anomalies, the precision of the cropping prediction on this calendar is no longer valid. In this paper, we consider the change point phenomena to improve the weather prediction in Daerah Istimewa Yogyakarta (DIY) Province as the adaptation of the climate change.

From the fact that the observations are solely devoted to one event only, i.e. the rainfall, we assume that the rainfall events follow the Poisson process. In this case, we will calculate the rain probability when the rainfall is above 8 mm per day.

Our analysis is based on the change point method that was done by using a Bayesian approach via Markov Chain Monte Carlo (MCMC) methods. The Bayesian approach was used for estimating the change point parameters. We use Gibbs sampling algorithm, which is one of the MCMC algorithm, to complete the Bayesian analysis. We consider case studies in four regencies of DIY Province (Bantul, Gunung Kidul, Sleman, and Kulonprogo) for the period June 22nd, 2006 to June 21st, 2011. We show that the shifting pattern is approximately 25% compare with the original "Pranoto mongso". We also show that the shifting time of the rainy season for each regencies.

Keywords: Pranoto mangso, Poisson Process, Bayesian Inference, change point, MCMC methods

1 Introduction

The direct effect of the global climate change is the major threat for the sustainability of the food security (Travis and Daniel, 2012). The temperature increase, the rainfall pattern change, and the extreme weather events due to the climate change which declines the growth period of the plant and the crop yield are the challenge to meet the food needs (Yinhong et al., 2009).

The important results of several studies on the climate change effects for cropping production show that the climate change is significantly affect the settlement of the three major food crops, i. e. rice, maize and wheat (Challinor and Wheeler, 2008; Aggarwal et al., 2006). The authors in Las et al. (2011) reported that the climate change effect can reduce the national rice production from 2.45 to 5.0%.

The crop production reduction due to climate change, is mainly due to the changes of rainfall patterns and the shifting time-start of the season (Anonymous, 2011). This shifting pattern of the season disrupts traditional cropping pattern which is adopted by the farmer, especially in DIY Province. At this time, the discrepancy between the prediction via the traditional cropping calendar “Pranoto mongso” and the real conditions as the effect of the global climate change is more increased. The shifting season start can led the crop water shortage in critical time or flood at the time when the plant do not require more water such as in harvesting time. In Las et al. (2011), the authors reported that in the planted areas which are suffered the crop failure (puso) due to drought reaches 0.04 to 1.87%, while the crop failure by floods reaches 8.7 to 13.8%.

The Pranoto mongso rule for the summer time which is usually used by the rural farmers is based on the experience of ancestors and used as a benchmark for the agricultural processing. Related to traditional knowledge, the Pranoto mongso provides an advise to farmers to follow the signs of nature in mongso concerned for cropping strategy. The Pranoto mongso calendar consists twelve sub-periods which is called “mongso” in one year. The calculations of the “mongso” is based on the people shadow when they stand upright from the sun at midday, with the initial provisions for "mongso" unit (gauze) is when the length of the shadow of four "halibut" in the south. The "halibut" is the sole of the foot, from the heel to the tip of the big toe. The next turn of the "mongso" occur consecutively, as long as the shadow in the midday is three halibut, two halibut, one halibut, and without the shadow. The next "mongso" is when the halibut is in the north, i.e. two halibut and one halibut, and then back without the shadow. After that, the shadow turned to the south enlarged and continue back to four halibut in the south.

Based on the description above, in order to avoid the failure of the crop production in DIY Province, it is necessary to improve the planting calendar based on the analysis, interpretation and modeling data of the local climate and landscapes in the area DIY which is more accurate and easier to apply.

2. Bayesian change point model for climate change

In this section, we discuss breafly the change point model. We assume the rainfall data as a Poisson process with density $f(x_i) = \lambda$ and the change point at τ as an unknown time and x_i the time between events. So the change point model with density function as follows,

$$f(x_i) = \begin{cases} \lambda_1 & , \quad 0 \le \sum_{k=1}^{i} x_k \le \tau \\ \lambda_2 & , \quad \sum_{k=1}^{i} x_k > \tau \end{cases} \tag{1}$$

The Equation (1) indicates that the change of density occurs at the change point τ from λ_1 to λ_2.

Given the model point change in equation (1) with the event data x_i. It is assumed that x_i is exponentially distributed with parameter as in equation (1) for $i = 1,2,3,...,n$. The new variable is defined

$$\varepsilon_i = \begin{cases} 1, & if \sum_{k=1}^{i} x_k \leq \tau \\ 0, & if \sum_{k=1}^{i} x_k > \tau \end{cases}$$

then density function of x_i is

$$f(x_i) = \begin{cases} \left(\lambda_1 e^{-\lambda_1 x_i}\right)^{\varepsilon_i} & , \quad x_i, \lambda_1, \lambda_2 > 0 \\ \left(\lambda_2 e^{-\lambda_2 x_i}\right)^{1-\varepsilon_i}, & otherwise \end{cases}$$

Likelihood function of λ_1, λ_2 and τ is

$$L(\lambda_1, \lambda_2, \tau \mid D) = \prod_{i=1}^{N(T)} f(x_i \mid \lambda_1) f(x_i \mid \lambda_2)$$
$$= \lambda_1^{N(\tau)} e^{-\lambda_1 \tau} \lambda_2^{N(T)-N(\tau)} e^{-\lambda_2 (T-\tau)} \tag{2}$$

where $D = (x_1, x_2, x_3, ..., x_n)$, $N(\tau) = \sum_{i=1}^{N(T)} \varepsilon_i$, $N(T) = \sum_{i=1}^{N(T)} 1 = n$,

$\tau = \sum_{i=1}^{N(T)} x_i \varepsilon_i$ and $T - \tau = \sum_{i=1}^{N(T)} x_i (1 - \varepsilon_i)$.

The likelihood function in Equation (2) then used in the analysis to obtain the Bayesian posterior distribution. The purpose of this step is to estimate the parameters of the point of change. Made under the theory of Bayesian inference and using Markov Chain Monte Carlo (MCMC). Maximum likelihood method can be used to estimate the parameters, but the Bayesian approach using MCMC method has some advantages that are not owned by maximum likelihood method, namely the use of expert opinions and prior information given by previous studies. In some cases, the use of classical inference method hampered difficulty inference when dealing with the case of the model change point. Therefore, in this case with a Bayesian analysis point change is made. Summary posterior obtained using MCMC methods.

The model is assumed to have a change point τ. The prior distribution of τ is non-informative prior, i.e. the discrete uniform $\pi_o(\tau = t_i)$.

The prior distribution of λ_1 and λ_2 is conjugate prior distribution from exponential family i.e. $Gamma(\alpha_0, \beta_0)$. Assuume that τ independent from λ_1 and λ_2, λ_1 independent from λ_2, given $\tau = t_i$, then we have

$$\pi(\lambda_1, \lambda_2, \tau = t_i) = \pi(\lambda_1, \lambda_2 | \tau = t_i)\, \pi(\tau = t_i)$$
$$\propto \lambda_1^{a_0 - 1}\, e^{-\lambda_1 \beta_0}\, \lambda_2^{a_0 - 1}\, e^{-\lambda_2 \beta_0}$$

where $\lambda_1, \lambda_2 > 0$. (3)

Based on equation (2) and (3), joint posterior distribution of λ_1, λ_2 and τ is

$$\pi(\lambda_1, \lambda_2, \tau | D) \propto L(\lambda_1, \lambda_2, \tau | D)\, \pi(\lambda_1, \lambda_2, \tau = t_i)$$
$$\propto \left[\lambda_1^{N(\tau)}\, e^{-\lambda_1 \tau}\, \lambda_2^{N(T)-N(\tau)}\, e^{-\lambda_2 (T-\tau)}\right]\left[\lambda_1^{a_0 - 1}\, e^{-\lambda_1 \beta_0}\, \lambda_2^{a_0 - 1}\, e^{-\lambda_2 \beta_0}\right]$$
$$\propto \lambda_1^{N(\tau)+a_0-1}\, e^{-\lambda_1(\tau+\beta_0)}\, \lambda_2^{N(T)-N(\tau)+a_0-1}\, e^{-\lambda_2(T-\tau+\beta_0)}$$

Finaly we have

$$\pi(\lambda_1, \lambda_2, \tau | D) = K(\tau)\, \lambda_1^{N(\tau)+a_0-1}\, e^{-\lambda_1(\tau+\beta_0)}\, \lambda_2^{N(T)-N(\tau)+a_0-1}\, e^{-\lambda_2(T-\tau+\beta_0)}$$

where

$$K(\tau) = \frac{(\tau + \beta_0)^{N(\tau)+\alpha_0}}{\Gamma(N(\tau) + \alpha_0)}\, \frac{(T - \tau + \beta_0)^{n-N(\tau)+\alpha_0}}{\Gamma(n - N(\tau) + \alpha_0)}$$

It shows that $\pi(\lambda_1, \lambda_2, \tau | D)$ is joint posterior distribution of two independent variables of $Gamma(\alpha_1, \beta_1)$ and $Gamma(\alpha_2, \beta_2)$.where

$\alpha_1 = N(\tau) + \alpha_0$, $\alpha_2 = n - N(\tau) + \alpha_0$

$\beta_1 = \tau + \beta_0$, $\beta_2 = T - \tau + \beta_0$

2.1 Gibbs *Sampling* Algorithm

Gibbs sampling is a simulation technique that is very useful to estimate the parameters. In this case, the necessary marginal posterior distribution of the parameters to be estimated, so it is expected that the results of the simulation using marginal distributions will converge to their joint posterior distribution.

Marginal posterior distribution of τ is

$$\pi(\tau | D) \propto \int_0^\infty \int_0^\infty \lambda_1^{N(\tau)+a_0-1}\, e^{-\lambda_1(\tau+\beta_0)}\, \lambda_2^{N(T)-N(\tau)+a_0-1}\, e^{-\lambda_2(T-\tau+\beta_0)}\, d\lambda_1\, d\lambda_2$$
$$\propto \frac{\Gamma(N(\tau) + a_0)\Gamma(n - N(\tau) + a_0)}{(\tau + \beta_0)^{N(\tau)+a_0}(T - \tau + \beta_0)^{n-N(\tau)+a_0}}$$

It follows that marginal distrbution of λ_1 and λ_2, given $\tau = \tau^*$.are

$$\lambda_1 | \tau^*, D \sim Gamma\left[N_{\tau^*}^{(\theta)} + \alpha_0, \tau^* + \beta_0\right]$$
$$\lambda_2 | \tau^*, D \sim Gamma\left[n - N_{\tau^*}^{(\theta)} + \alpha_0, T + \tau^* + \beta_0\right]$$

Gibbs *sampling* Algorithm:

1. initial value $\tau^{(0)}$, $\lambda_1^{(0)}$ and $\lambda_2^{(0)}$:
2. generate $\lambda_1^{(i+1)}$ by $\pi(\lambda_1 | \lambda_2^{(i)}, \tau^{(i)}, D)$
3. generate $\lambda_2^{(i+1)}$ by $\pi(\lambda_2 | \lambda_1^{(i)}, \tau^{(i)}, D)$

4. generate $\tau^{(i+1)}$
5. repeat step 1 until 3 until all of the estimators are convergent and no autocorrelation.

The estimators of τ , λ_1 and λ_2 are the mean of the sample of Gibbs *sampling*.

2.2 MCMC output analysis

There are some important things that must be considered in analyzing the MCMC output, i.e the burn-in sample and the convergence iteration, the disappearance of the autocorrelation and the small standard error. The burn-in is initialized by value are typically not derived from the posterior distribution with the simulation value of parameter λ_1, λ_2 and τ at the beginning of MCMC has no distribution of marginal posterior.

However, after several iterations performed (the end of the burn-in), the initial value of the new distribution iteration approaches marginal posterior distribution. The long-term burn-in is based simulated trace plots of each parameter. The up or down trends of the parameter values in the trace plot indicates that the burn-in period has not ended. In addition to the burn-in, which should be taken into consideration is the autocorrelation degree in the sampled values. In the Gibbs sampling algorithm, a simulation value of iteration parameter $(j+1)^{th}$ correlated with the values obtained in the iteration j^{th}. If the strong correlation results the bias value, then the algorithm indicates a weak mixing.

The selection of the number of samples and the accuracy of the calculation of the posterior is one of the most important parts that must be considered. Standard error MCMC is very useful to determine the accuracy of the average posterior simulation. If the MCMC has large standard error, then the MCMC algorithms would be repeated with a larger number of iterations. The repetition is sufficient when the standard error of the MCMC is small.

3. Estimation of “Pranoto Mongso” in DIY

One of the application of Bayesian method via Gibbs sampling point is the climate change model to estimate the Pranoto Mongso in DIY.

We use the rainfall data of DIY which is obtained from the Agency of Meteorology, Climatology, and Geophysics (BMKG) Yogyakarta. We consider the occurrence of the rain in one day with the rainfall above 8 mm in the period from June 22, 2006 until June 21, 2011 is the events in this paper.

From the change point model analysis we can conclude that Pranoto mongso in DIY in the period from June 22, 2006 until June 21, 2011 experienced a shift of approximately 25% from the original Pranoto mongso, see Table 1. We show the shifting rainfall pattern for four of four regencies in DIY in the Appendix.

The Sleman pattern has been shown on Table 2 and Table 3, the Kulon Progo pattern is in Table 4,5, and 6, the Bantul pattern is on Table 7 and 8, and the Gunung Kidul pattern is shown on Table 9 and 10. The changes of Pranoto mongso in general consist of a delay in the arrival of the rainy season for ± 1 month, short transition seasons due to the duration of sparse rain and mareng reduced ± 1 months and increased the length of the duration of the dry season longer ± 1 month of original Pranoto mongso as in Table 1.

Table 1. Pranoto Mongso (*Original*)

Month	Mongso	Natural conditions
22 Dec – 2 Feb	Kapitu	Rainy
3 Feb – 28/29 Feb	Kawolu	Sparse rain
1 Mar – 25 Mar	Kasongo	
26 Mar – 18 Apr	Kasadasa	Mareng
19 Apr – 11 Mei	Desta	
12 Mey – 21 June	Sadha	Dry
22 June – 1 Ags	Kasa	
2 Ags – 24 Ags	Karo	
25 Ags – 17 Sep	Ketiga	
18 Sep – 12 Oct	Kapat	Sparse rain
13 Oct – 8 Nov	Kalima	Rainy
9 Nov – 21 Dec	Kanem	

4. Conclusion

From the climate data analysis, we can conclude that the estimation using Bayesian method is easier to do with Gibbs sampling and the estimator of parameters are obtained by the mean of Gibbs sampling.

The results of the case study on DIY shows that the Pranato mangso in DIY (Bantul, Gunung Kidul, Kulon Progo and Sleman) in the period from June 22, 2006 until June 21, 2011 experienced a shift of approximately 25% from the previous pranoto mongso table 1 (original).

The changes of the pranato mangso in general consist of a delay in the arrival of the rainy season for ± 1 month. Farmers require planting an accurate calendar in accordance with their regional and easy to understand and do.

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APPENDIX

The Shifted Rainfall Pattern in DIY

Table 2. The Estimation of Pranoto mongso in BMKG Yogyakarta

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 12 Mar (0,6)	22 Dec - 16 Mar (0,6)	22 Dec - 25 Feb (0,5)	22 Dec - 6 Mar (0,6)	22 Dec - 20 Feb (0,5)
3 Feb - 28/29 Feb	Kawolu	Sparse rain					
1 Mar - 25 Mar	Kasongo		13 - 20 Mar (0,4)	17 - 29 Mar (0,4)	26 Feb - 28 Mar (0,4)		
26 Mar - 18 Apr	Kasadasa	Mareng	21 Mar -14 Mey (0,3)	30 Mar - 20 Apr (0,3)	29 Mar - 5 Mey (0,3)	7 Mar - 15 Apr (0,4)	21 Feb – 2 Apr (0,4)
19 Apr - 11 Mey	Decta						3 Apr - 5 Mey (0,3)
12 Mey - 21 June	Sadha						
22 June - 1 Ags	Kasa	Dry				16 Apr - 25 Agt (0,3)	
2 Ags - 24 Ags	Karo		15 Mey - 30 Oct (0,2)	21 Apr – 20 Oct (0,2)	6 Mey -23 Oct (0,2)		6 Mey - 28 Oct (0,2)
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain				29 Sep - 8 Nov (0,4)	
13 Oct - 8 Nov	Kalima	Rainy	31 Oct - 5 Nov (0,4)	21 Oct – 8 Nov (0,4)	24 Oct - 17 Nov (0,4)		29 Oct - 5 Nov (0,4)
9 Nov - 21 Dec	Kanem		6 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,5)	18 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,5)	6 Nov - 21 Dec (0,5)

Table 3. The Estimation of Pranoto mongso in Prambanan

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy			22 Dec - 7 Mar (0,5)	22 Dec – 5 Mar (0,5)	22 Dec - 14 Mar (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain	22 Dec - 4 Apr (0,5)	22 Dec - 3 Mar (0,5)			
1 Mar - 25 Mar	Kasongo				8 Mar – 2 Apr (0,4)	6 Mar - 24 Apr (0,4)	15 Mar - 3 Apr (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng	5 Apr - 15 Mey (0,4)	4 Mar - 8 Apr (0,4)	3 Apr - 18 Mey (0,3)		4 Apr - 5 Mey (0,3)
19 Apr - 11 Mey	Decta			9 Apr - 22 Mey (0,3)		25 Apr - 14 Mey (0,3)	
12 Mey - 21 June	Sadha		16 Mey - 27 June (0,3)				
22 June - 1 Ags	Kasa	Kemarau		23 Mey - 22 Oct (0,2)	19 Mey - 23 Oct (0,2)	15 Mey – 14 Oct (0,2)	
2 Ags - 24 Ags	Karo		28 June - 28 Oct (0,2)				6 Mey - 4 Nov (0,2)
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain					
13 Oct - 8 Nov	Kalima	Rainy	29 Oct - 10 Nov (0,4)	23 Oct - 8 Nov (0,4)	24 Oct - 17 Nov (0,4)	15 Oct - 9 Nov (0,4)	
9 Nov - 21 Dec	Kanem		11 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,5)	18 Nov - 21 Dec (0,5)	10 Nov - 21 Dec (0,5)	5 Nov - 21 Dec (0,5)

Table 4. The Estimation of Pranoto mongso in Galur

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 18 Mar (0,5)		22 Dec - 25 Feb (0,5)	22 Dec - 9 Mar (0,5)	22 Dec - 12 Mar (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain		22 Dec - 21 Mar (0,5)			
1 Mar - 25 Mar	Kasongo		19 Mar - 14 Apr (0,4)		26 Feb - 25 Mar (0,4)	10 Mar - 24 Apr (0,4)	13 Mar - 2 Apr (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng		22 Mar - 4 Apr (0,4)	26 Mar - 11 Mey (0,3)		3 - 30 Apr (0,3)
19 Apr - 11 Mey	Decta		15 Apr - 15 Mey (0,3)			25 Apr- 16 Mey (0,3)	
12 Mey - 21 June	Sadha						
22 June - 1 Ags	Kasa	Kemarau		5 Apr - 15 Oct (0,2)			
2 Ags - 24 Ags	Karo		16 Mey - 30 Oct (0,2)		12 Mey - 26 Oct (0,2)	17 Mey - 13 Oct (0,2)	1 Mey - 6 Nov (0,2)
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain					
13 Oct - 8 Nov	Kalima	Rainy	31 Oct - 13 Nov (0,4)	17 Oct - 2 Nov (0,4)	27 Oct - 13 Nov (0,4)	14 Oct - 9 Nov (0,4)	
9 Nov - 21 Dec	Kanem		14 Nov - 21 Dec (0,5)	3 Nov- 21 Dec (0,6)	14 Nov - 21 Dec (0,5)	10 Nov - 21 Dec (0,5)	7 Nov - 21 Dec (0,7)

Table 5. The Estimation of Pranoto mongso in Lendah

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 20 Mar (0,5)	22 Dec - 19 Feb (0,5)	22 Dec – 25 Feb (0,5)	22 Dec - 9 Mar (0,5)	22 Dec - 28 Feb (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain					
1 Mar - 25 Mar	Kasongo		21 - 31 Mar (0,4)	20 - 22 Mar (0,4)	26 Feb – 2 Apr (0,4)	10 Mar - 27 Mar (0,3)	1 Mar - 5 Apr (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng	1 Apr - 15 Mey (0,3)	23 Mar - 4 Apr (0,3)	3 - 25 Apr (0,3)	28 Mar - 16 Mey (0,3)	6 - 30 Apr (0,3)
19 Apr - 11 Mey	Decta						
12 Mey - 21 June	Sadha						
22 June - 1 Ags	Kasa	Kemarau		5 Apr - 8 Oct (0,2)	25 Apr - 26 Oct (0,2)		
2 Ags - 24 Ags	Karo		16 Mey - 30 Oct (0,2)			17 Mey - 24 Sep (0,2)	1 Mey - 9 Nov (0,2)
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain		9 - 25 Oct (0,4)			
13 Oct - 8 Nov	Kalima	Rainy	31 Oct - 13 Nov (0,4)	26 Oct - 21 Dec (0,6)	27 Oct - 13 Nov (0,4)	25 Sep - 9 Nov (0,4)	
9 Nov - 21 Dec	Kanem		14 Nov - 21 Dec (0,5)		14 Nov - 21 Dec (0,5)	10 Nov - 21 Dec (0,5)	10 Nov - 21 Dec (0,5)

Table 6. The Estimation of Pranoto mongso in Sentolo

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 20 Mar (0,5)	22 Dec - 21 Feb (0,5)	22 Dec - 24 Mar (0,5)	22 Dec - 6 Mar (0,5)	22 Dec - 29 Feb (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain					
1 Mar - 25 Mar	Kasongo		21 Mar - 6 Apr (0,4)	22 Feb - 23 Mar (0,4)	25 Mar - 12 Apr (0,4)	7 Mar - 22 Apr (0,4)	1 - 30 Mar (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng		24 Mar - 22 Apr (0,3)	13 Apr - 7 Mey (0,3)		1 Apr - 6 Mey (0,3)
19 Apr - 11 Mey	Decta					23 Apr - 7 June (0,3)	
12 Mey - 21 June	Sadha		7 Apr - 18 June (0,3)				
22 June - 1 Ags	Kasa	Kemarau		23 Apr - 15 Oct (0,2)	8 Mey - 20 Oct (0,2)	8 June - 17 Oct (0,2)	
2 Ags - 24 Ags	Karo		19 June - 28 Oct (0,2)				7 Mey - 10 Nov (0,2)
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain					
13 Oct - 8 Nov	Kalima	Rainy	29 Oct - 12 Nov (0,4)	16 Oct - 8 Nov (0,4)	21 Oct - 15 Nov (0,4)	18 Oct - 22 Nov (0,4)	
9 Nov - 21 Dec	Kanem		13 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,6)	16 Nov - 21 Dec (0,5)	23 Nov - 21 Dec (0,6)	11 Nov - 21 Dec (0,5)

Table 7. The Estimation of Pranoto mongso in Nyemengan

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy		22 Dec - 11 Mar (0,5)	22 Dec - 13 Feb (0,5)		22 Dec - 17 Mar (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain	22 Dec - 28 Mar (0,5*)			22 Dec - 26 Mar (0,5)	
1 Mar - 25 Mar	Kasongo			12 - 19 Mar (0,4)	14 - 21 Mar (0,4)		18 - 22 Mar (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng	29 Mar - 10 Apr (0,4)	20 Mar - 7 Apr (0,3)	22 Mar - 18 Mey (0,3)	27 Mar – 22 Apr (0,4)	23 Mar - 24 Apr (0,3)
19 Apr - 11 Mey	Decta		11 Apr - 15 Mey (0,3)			23 Apr - 16 Mey (0,3)	
12 Mey - 21 June	Sadha						
22 June - 1 Ags	Kasa	Kemarau		8 Apr - 19 Oct (0,2)			25 Apr - 23 Oct (0,2)
2 Ags - 24 Ags	Karo		16 Mey - 29 Oct (0,2)		19 Mey - 24 Oct (0,1)	17 Mey - 15 Oct (0,2)	
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain					
13 Oct - 8 Nov	Kalima	Rainy	30 Oct - 13 Nov (0,4)	20 Oct - 8 Nov (0,4)	25 Oct - 16 Nov (0,4)	16 Oct - 8 Nov (0,4)	24 Oct - 1 Nov (0,4)
9 Nov - 21 Dec	Kanem		14 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,5)	17 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,6)	2 Nov - 21 Dec (0,5)

Table 8. The Estimation of Pranoto mongso in Kotagede

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 2 Mar (0,5)	22 Dec - 5 Feb (0,5)	22 Dec - 19 Mar (0,6)	22 Dec - 10 Mar (0,6)	22 Dec - 14 Mar (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain		6 - 15 Feb (0,4)			
1 Mar - 25 Mar	Kasongo		3 Mar - 3 Apr (0,4)	16 Feb - 26 Mar (0,3)	20 Mar - 19 Apr (0,4)	11 Mar - 14 Apr (0,4)	15 Mar - 1 Apr (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng	4 - 18Apr (0,3)	27 Mar - 19 Oct (0,2)		15 Apr - 12 June (0,3)	2 Apr - 5 Mey (0,3)
19 Apr - 11 Mey	Decta		19 Apr - 12 Oct (0,2)		20 Apr – 17 Mey (0,3)		6 Mey - 8 Nov (0,2)
12 Mey - 21 June	Sadha	Kemarau			18 Mey – 11 Nov (0,2)	13 June - 22 Oct (0,2)	
22 June - 1 Ags	Kasa						
2 Ags - 24 Ags	Karo						
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain	13 Oct - 3 Nov (0,4)	20 Oct - 26 Oct (0,4)			
13 Oct - 8 Nov	Kalima	Rainy	4 Nov - 21 Dec (0,7)	27 Oct - 21 Dec (0,6)		23 Oct - 13 Nov (0,4)	
9 Nov - 21 Dec	Kanem				12 Nov - 21 Dec (0,5)	14 Nov - 21 Dec (0,7)	9 Nov - 21 Dec (0,6)

Table 9. The Estimation of Pranoto mongso in Playen

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 9 Apr (0,5)	22 Dec - 29 Feb (0,5)	22 Dec - 23 Mar (0,5)	22 Dec - 9 Mar (0,5)	22 Dec - 5 Mar (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain					
1 Mar - 25 Mar	Kasongo			1 - 8 Mar (0,4)	24 - 29 Mar (0,4)	10 Mar - 24 Apr (0,4)	6 - 19 Mar (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng	10 - 27 Apr (0,4)	9 Mar - 3 Apr (0,2)	30 Mar - 20 Apr (0,3)		20 Mar – 18 Apr (0,3)
19 Apr - 11 Mey	Decta		28 Apr - 19 Mey (0,3)	4 Apr - 19 Oct (0,2)	21 Apr – 24 Oct (0,2)	25 Apr - 14 Mey (0,3)	19 Apr - 25 Oct (0,2)
12 Mey - 21 June	Sadha	Kemarau	20 Mey - 2 Nov (0,2)			15 Mey - 17 Oct (0,2)	
22 June - 1 Ags	Kasa						
2 Ags - 24 Ags	Karo						
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain					
13 Oct - 8 Nov	Kalima	Rainy	2 Nov - 21 Dec (0,6)	20 Oct - 3 Nov (0,4)	25 Oct - 13 Nov (0,4)	18 Oct - 9 Nov (0,4)	26 Oct - 21 Dec (0,5)
9 Nov - 21 Dec	Kanem			4 Nov - 21 Dec (0,6)	14 Nov - 21 Dec (0,5)	10 Nov - 21 Dec (0,5)	

Table 10. The Estimation of Pranoto mongso in Ngawen

Month	Mongso	Natural conditions	Estimation of 2006-2007	Estimation of 2007-2008	Estimation of 2008-2009	Estimation of 2009-2010	Estimation of 2010-2011
22 Dec - 2 Feb	Kapitu	Rainy	22 Dec - 13 Apr (0,5)	22 Dec - 25 Feb (0,6)	22 Dec - 2 Mar (0,5)	22 Dec - 6 Mar (0,5)	22 Dec - 5 Mar (0,5)
3 Feb – 28/29 Feb	Kawolu	Sparse rain					
1 Mar - 25 Mar	Kasongo			26 Feb - 8 Mar (0,4)	3 Mar - 18 Apr (0,4)	8 - 26 Mar (0,4)	6 - 31 Mar (0,4)
26 Mar - 18 Apr	Kasadasa	Mareng	14 Apr – 17 Mey (0,4)	9 - 21 Mar (0,3)		26 Mar - 14 Mey (0,3)	1 Apr – 29 Mey (0,3)
19 Apr - 11 Mey	Decta		18 Mey – 30 Mey (0,3)		19 Apr - 21 Mey (0,3)		
12 Mey - 21 June	Sadha	Kemarau	31 Mey – 20 Oct (0,2)	20 Apr - 13 Oct (0,2)	22 Mey - 22 Oct (0,2)	15 Mey - 16 Sep (0,2)	30 Mey – 17 Oct (0,2)
22 June - 1 Ags	Kasa						
2 Ags - 24 Ags	Karo						
25 Ags - 17 Sep	Ketiga						
18 Sep - 12 Oct	Kapat	Sparse rain					
13 Oct - 8 Nov	Kalima	Rainy	21 Oct – 10 Nov (0,4)	14 Oct - 10 Nov (0,4)	23 Oct - 12 Nov (0,4)	14 Oct - 8 Nov (0,4)	18 Oct - 9 Nov (0,4)
9 Nov - 21 Dec	Kanem		11 Nov - 21 Dec (0,6)	11 Nov - 21 Dec (0,5)	13 Nov - 21 Dec (0,5)	9 Nov - 21 Dec (0,6)	10 Nov - 21 Dec (0,5)

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